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MEASURING THE RESISTANCE OF TIRES FOR PASSENGER VEHICLE AGAINST THE ROLLING AND SLIDING ON LOADING AREA OF THE FLATBED TRUCK WHEN PROVIDING THE TRANSPORT SERVICES

This paper deals with the size of the forces affecting the vehicle during the transportation on a flatbed truck, railway wagon or container. It is necessary to secure the vehicle against these forces properly in order to prevent vehicle´s replacement. The laboratory measurements were performed in order to find out the size of coefficient of friction between the tire and the vehicle´s loading area. During the measurements, vehicle had different gears in order to determine to what extent the size of mechanical resistances affects the fixing and securing the vehicle against its replacement on the loading area. However, this paper does not propose the solution for securing the passenger vehicle on the loading area of a truck, railway wagon or container.

Keywords: *Mechanical resistances of the vehicle, fixing, securing, loading area, sliding friction, dynamic coefficient of the sliding friction.*

1. Introduction

These days, vehicle has become a common part of our lives and this factor has represented the impulse for substantial increase of vehicle production. The Slovak Republic has become an important vehicle manufacturer with production of almost 1 million vehicles per year. This represents the significant part of the whole industrial production in the Slovak Republic. Vehicles need not only be manufactured, but also transported to the determined place. An important part of safe transportation is the proper cargo fixing and securing on the loading area of a truck, railway wagon or container. The objective is to determine and subsequently evaluate the physical phenomenon forming while rolling and sliding the tire (wheel) [1 - 3].

2. The interaction of wheel and surface

Forces generated between the wheel and surface present a specific case of force transmission. The flexible part (rubber of the tread) is in contact with a rough unyielding surface (road, transport vehicle floor, etc.) [2].

Friction is an essential part of our existence. Friction is the result of mutual forces of two surfaces which are compressed with the certain force. There would be no vehicle or bicycle movements, or any other activities, such as walking or even pen writing, without this phenomenon. Nodes would be spontaneously loosened and woven fibers would be spontaneously disintegrated easily [3].

While the body is moving on the surface, firstly, a short connection and then sliding the contact surfaces are initiated. Repeating the sliding and connecting the contact surfaces might cause their oscillation. This phenomenon could be accompanied by the different sounds which were heard while measuring, particularly, when vehicle wheels were secured against their rotation by handbrake. Friction can be static and dynamic [2 - 4].

2.1 Sliding friction and frictional forces

Sliding friction is a physical phenomenon that occurs when the body is moving (sliding) on the surface of another body. Its origin is mainly in the roughness of both contact surfaces which connect the bodies with each other. Rough nesses of different areas and surfaces impinge, deform and abrade between each

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other when the bodies are sliding. That represents the origin of frictional force. The point of application of frictional force is on the contact surfaces of both bodies and its direction is always heading upstream the direction of movement of the body. Frictional force does not depend on the size of contact surfaces, but only on the amount of force which presses the surfaces to each other (see Fig. 1) [1 and 4].

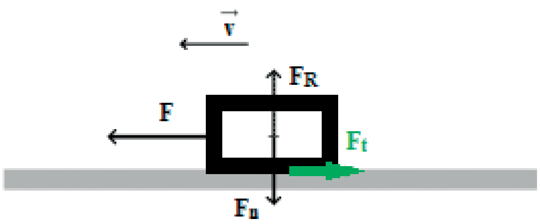

Fig. 1 Forces generated during the sliding friction, Source: Authors

If the surfaces were stationary at the beginning of acting the F force, firstly, it would be necessary to achieve the overcoming of the forces caused by the roughness of surfaces that interact with each other. Friction resistance decreases after the overcoming of these forces, because the roughness of surfaces has no longer an option of intense defense against the mutual sliding. Figure 2 presents the measuring of the sliding friction force from the beginning of its acting when the block is in the rest through the commencing of the movement until the uniform motion. This situation concerns the time when the body starts moving and frictional force starts reducing subsequently [1, 3 and 4].

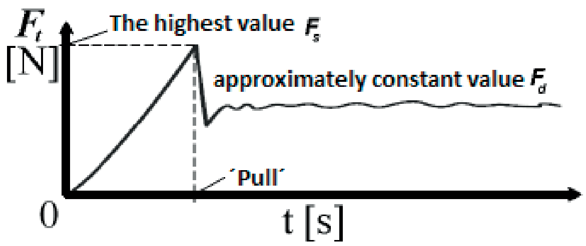

Fig. 2 Dependence of increasing force acting on the body which needs to be set in motion, Source: Authors

The amount of force F_s reaches the maximum value $F_{s,max}$ given by the formula (1):

$$F_{s\max} = \mu_s * F_n \tag{1}$$

where μ_s is the static coefficient of friction, F_n is the amount of the normal compressive force that presses the body to the surface, F_R is the size of response of the surface - it is equally large but oppositely directed as the force F_n.

In case the force F, acting on the body, is greater than $F_{s,max}$, the body begins to move. In this moment, the friction force to keep the body in movement decreases and F_d is sufficient. The amount of this force can be determined with the following formula (2):

$$F_d = \mu_d * F_n \tag{2}$$

where μ_d is the coefficient of dynamic (kinetic) friction.

During the whole movement, the value of dynamic friction force F_d remains the same [3 and 4].

3. Methodology for measuring the mechanical resistance and its evaluation

The methodology was determined on the basis of Annex B of standard STN EN 12195-1:2011, which provides two possible alternative procedures. For determining the friction coefficient during the measurement, the appropriate procedure was defined in the Standard STN in paragraph B.1.3 of the Annex B - *Tensile test* [5].

3.1 Vehicle used for the measurement

The measurements were made with the passenger vehicle DAEWOO KALOS. Its dimensions and parameters are presented in Table 1. A more detailed specification of tires is shown in Table 2.

Dimensions and parameters of the vehicle DAEWOO KALOS — Table 1

Length	3880 mm
Width	1670 mm
Height	1495 mm
Wheelbase	2480 mm
Mass	960 kg

Source: Authors

The measurements were done in laboratories of the Department of Road and Urban Transport - University of Zilina. A hydraulic cylinder was used in order to create the necessary tension force. It is shown in Fig. 3.

Due to the possibilities of piston ejecting and the Annex B of standard STN EN 12195-1:2011, a distance of one movement (pull) up to 80 mm and follow-up force release at least 30% in every effort were chosen. This distance was manually controlled using the control unit through which the piston moved [3, 5 and 6].

A more detailed specification of the vehicle DAEWOO KALOS tires

Table 2

Tires	BARUM Polaris 3 175/70 R13 82T
Manufacturer	BARUM
Speed Index	T = 190 km/h
Load Index	82 = 475 kg
Class fuel economy	F
Wet grip class	C
Noise level	71dB
Inflation Pressure	220 kPa front
	210 kPa rear
Kind	winter

Source: Authors

It was decided to use the plywood in order to achieve the most faithful simulation of surface of the flatbed truck loading area. All measurements were performed on both sides of plywood - on a smooth and rough side [6 - 9].

Fig. 3 Connection of the vehicle to the piston by the towing device at the back, Source: Authors

Evaluated results using the statistical values for the vehicle secured by the gear backward (reverse gear) are presented in the following Table 3.

Graphical representation of mixed coefficient of resistance against the movement for the vehicle secured by the gear backward is illustrated in the following Fig. 4.

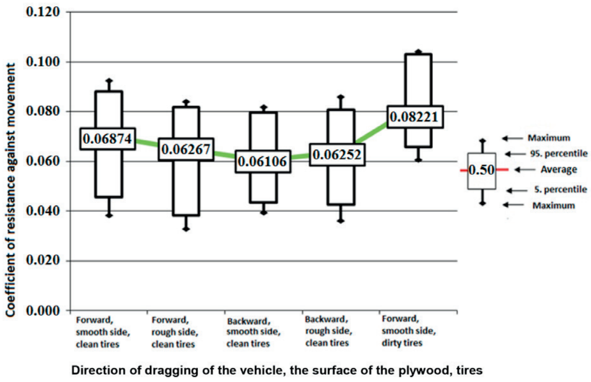

Fig. 4 Chart of mixed coefficient of resistance against the movement for the vehicle secured by the gear backward. Source: Authors

When securing the car by the gear backward, it can be noticed that the increase and decrease of the force depends not only on the track (route) and speed of dragging (pulling). Above all, it depends on the current position of the vehicle transmission system which varies according to the traveled distance. Transmission system and the vehicle engine have the most significant impact on the value of the coefficient [8, 9 and 10].

The amount of force for the vehicle secured by the gear backward is shown in Fig. 5.

Results using the statistical values for the vehicle secured by the gear backward

Table 3

	Forward, plywood smooth side, clean tires	Forward, plywood rough side, clean tires	Backward, plywood smooth side, clean tires	Backward, plywood rough side, clean tires	Forward, plywood smooth side, dirty tires
Minimum	0.03823	0.03292	0.03929	0.03610	0.06052
Maximum	0.09238	0.08389	0.08176	0.08601	0.10410
Average	0.06874	0.06267	0.06106	0.06252	0.82210
Median	0.07008	0.06477	0.06052	0.06371	0.08282
Modus	0.08070	0.07539	0.04991	0.07008	0.92380
Standard deviation	0.01375	0.01349	0.01176	0.01257	0.01162
Range	0.05415	0.05097	0.04247	0.04991	0.04354
5. percentile	0.04570	0.03820	0.04350	0.04250	0.06570
25. percentile	0.05730	0.05200	0.05100	0.05200	0.07480
75. percentile	0.08070	0.07430	0.07110	0.07330	0.09190
95. percentile	0.08810	0.08180	0.07960	0.08070	0.10310

Source: Authors

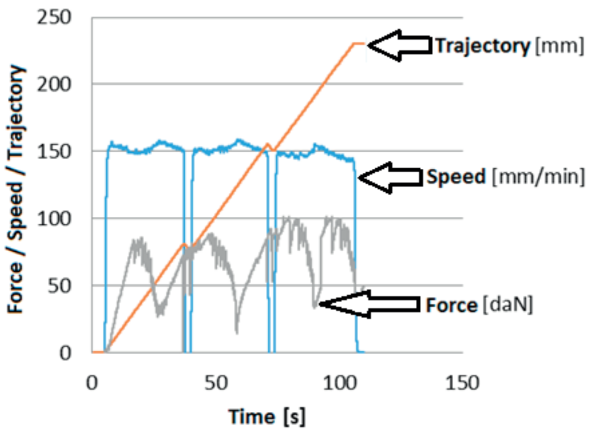

Fig. 5 Representation of the amount of force for the vehicle secured by the gear backward, Source: Authors

3.2 The impact of a particular gear on the coefficient of resistance against the movement

The following Table 4 presents the amount of force (in percentage) needed to overcome the total resistance against the vehicle movement. This means how great must be the force in order to put the vehicle in motion when the vehicle is secured by the gear [9 and 12].

The amount of force needed to overcome the total resistance against the vehicle movement Table 4

Gear	Force presented by the percentage	Percentage comparison compared to the first gear
R - reverse	103.35 %	+ 3.35 %
1	100.00 %	-
2	58.10 %	- 41.90 %
3	47.49 %	- 52.51 %
4	38.55 %	- 61.45 %
5	32.40 %	- 67.60 %

Source: Authors

From the table above, it was found out that the greatest force to put the vehicle in motion is needed with the gear backward (reverse gear). Slightly less force is needed for the first gear. For the second gear, the force of amount 41.9% lower than the first gear is needed to put the vehicle in motion. As for the fourth gear, the necessary force is by 61.45% lower than the first gear. Specific amounts of forces are shown in the following chart - Fig. 6 [4, 5, 11 - 14].

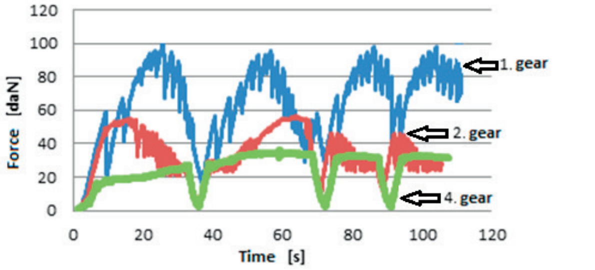

Fig. 6 Graphical representation of the amount of the force with different gears, Source: Authors

4. Conclusion

Based on the results, it can be concluded that if the vehicle is secured against undesirable movement only by the gear, the current position of the vehicle transmission system has a significant impact. Position is changed according to the traveled distance.

Direction of dragging (pulling) the vehicle, as well as the surface of pad, does not affect the results of the measurements significantly, since no sliding was in this case. Mud stained tires had slight effect on the increase of the coefficient in the measurements performed with the reverse gear [14 and 15].

It was also found out that the greatest force for putting the car in motion from the rest to "move back" position is needed by reverse gear securing, provided the car is not secured any other way. Vice versa, the lowest value of the force is sufficient for the highest gear, the fifth gear in this case [4 and 16].

When securing the vehicle on the loading area only by the gear, it is necessary to consider the dynamics of the movement (acceleration and deceleration), which may cause that the engine resistance will be overcome and crankshaft will be rotated. So, this would cause the unwanted vehicle replacement. The possibility that the driver set the gear (I, R) incompletely is another risk. During the transport services, due to the dynamics of the movement, it could lead to the spontaneous setting to neutral and this would mean that the vehicle is be able to move freely on the loading area [3, 6 and 17].

Securing the vehicle on the loading area only by a gear is insufficient (as shown in Fig. 5), also on the basis of the necessary securing force 0.8 times of *g* in the direction of traveling (forward) and to the sides and 0.5 times *g* backward.

Measurements clearly show that vehicles, during the transportation from the manufacturer to the customer, must be secured by the lashing straps [2 and 18].

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